Update on 4π control system

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KamLAND collaboration meeting, Gatlinburg, TN – April 2-4, 2005

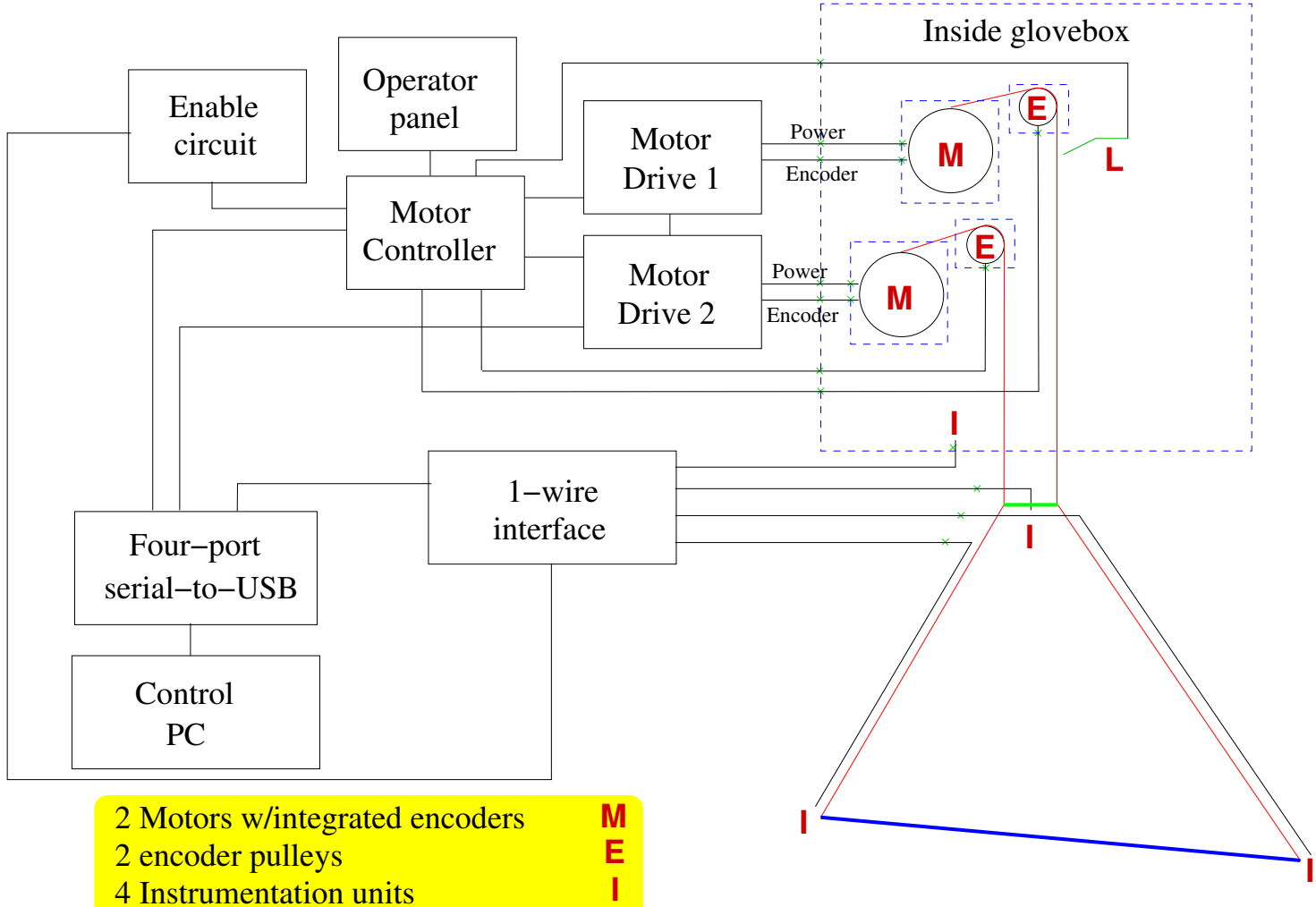
- Reminder of control system design
  - Concept is becoming reality!
- Summary of development and testing
- Remaining tasks

Multiple layers of protection

...against mistakes that might damage the detector:

1. Written deployment protocol.
2. Operator – required to move in small steps.
3. Pre-verification of commanded motion.
4. Continuous cross-checks between various position measurements.
5. Immediate stop if measured position goes outside allowed region.

Control hardware



2 Motors w/integrated encoders	M
2 encoder pulleys	E
4 Instrumentation units	I
1 Limit switch	L

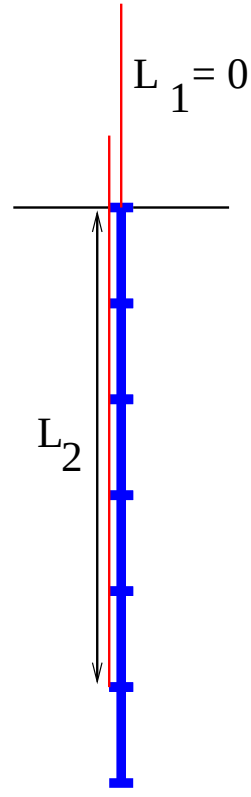
× = feedthrough required

Stages of deployment

- During assembly of pole: use external manual controller (no constraints).
- Tare procedure with top segment held in pin block.
- During calibration, until pole withdrawal begins, all constraints are enforced:
  - All position measurements in agreement:
    - Primary: cable lengths from encoder pulley
    - Cable lengths from motor encoder
    - Instrumentation unit pressure sensors
    - Instrumentation unit accelerometers (tilt sensors)
  - Physics model indicates all components of system in bounds.
  - Slack in lower cable does not exceed specified value.
- During pole disassembly, shift back to manual controller.

Tare procedure

- While top pole segment is held by pin block, pull both cables taut.

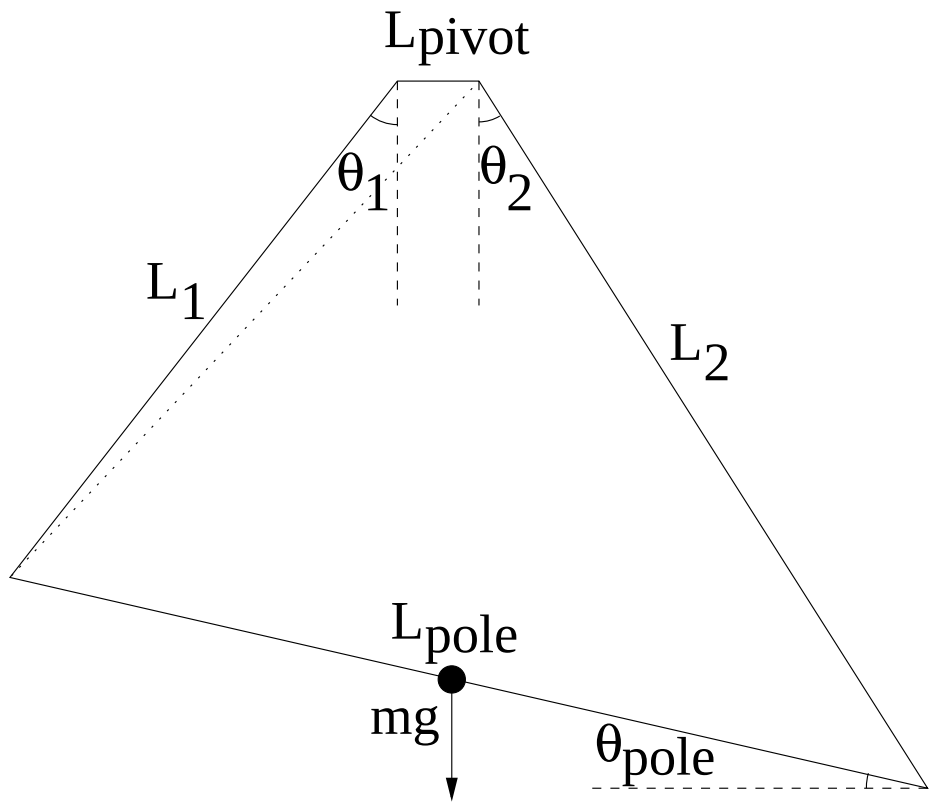


Basic tests

- Reproducibility of cable lengths within $\sim$ 1 mm
- Cable can be stopped by hand when motor torque limit is set properly.
- Motor-encoder interlock stops system if encoder feedback disappears.

Survey: angles

- Theodolite with digital readout used to measure coordinates of pivot block and cable attachment points.
- Angles θ_{pole}, θ_1, θ_2 computed.

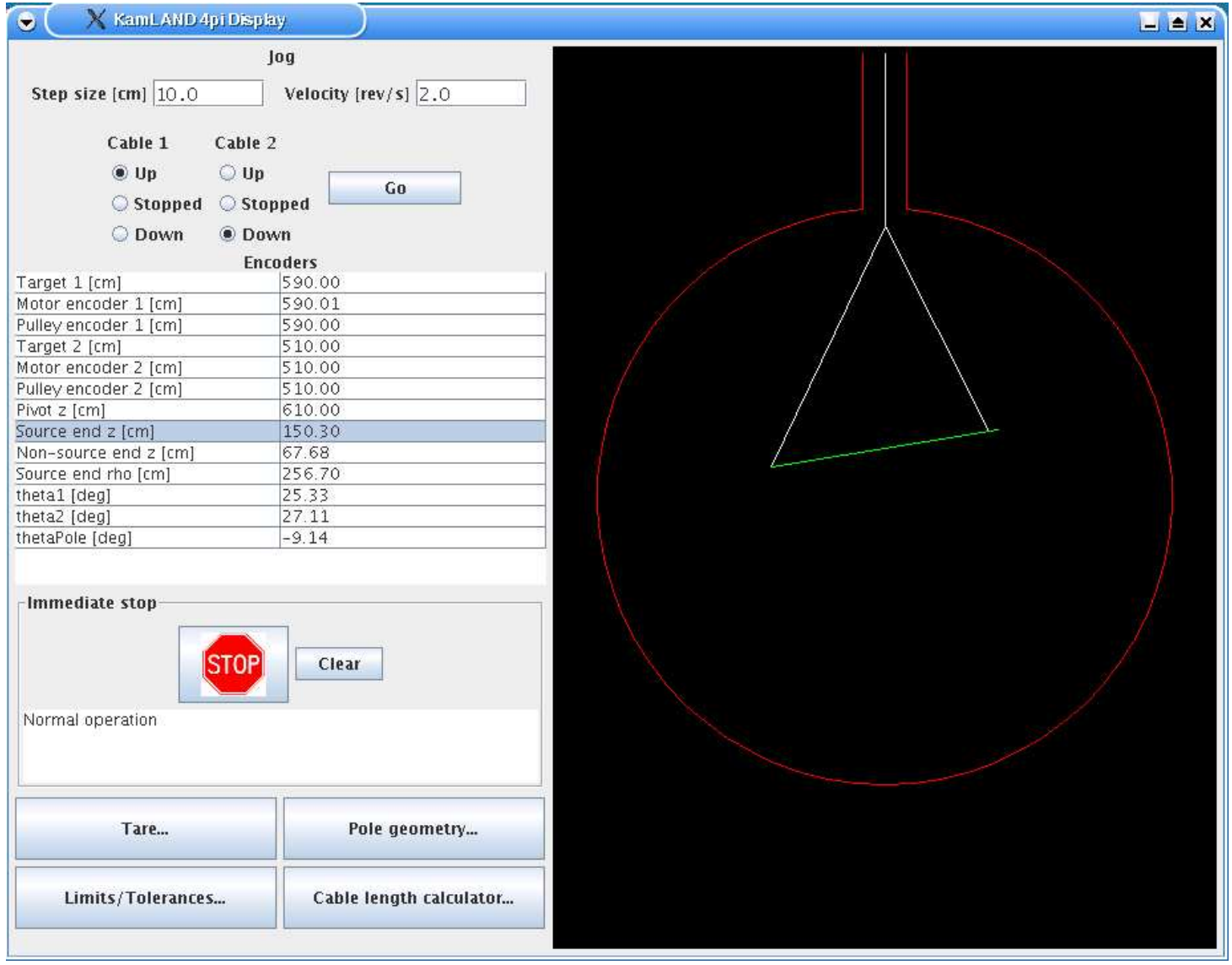


Survey: within a few degrees

	θ_{pole} Control	[deg] Survey	θ_1 Control	[deg] Survey	θ_2 Control	[deg] Survey
1	80.3	85.3	8.4	3.4	2.2	1.0
2	65.0	66.8	21.7	19.9	5.9	5.1
3	50.0	51.2	34.2	31.9	10.2	9.2
4	35.0	35.6	45.7	43.2	16.3	14.9
5	20.0	18.0	55.2	48.7	25.6	24.0
6	21.3	19.3	54.5	47.8	24.6	22.9
7	5.0	1.4	60.6	55.1	41.0	39.0
8	-0.1	-1.3	60.9	57.8	47.9	45.6
9	-5.0	-5.9	60.6	55.1	55.4	51.1

New z-axis mode interface

4π mode interface



Remaining tasks

- Integrate instrumentation units: add cross-checks between cable length and accelerometers/pressure sensors.
  - Currently solving electrical problems.
- Retension cables and recalibrate motor vs. pulley encoders.
- Re-enable the cross-checks that have been disabled for testing of partial system.
- Repeat survey measurements.
- Insert real detector geometry.
- Provide easier access to history information (partially done: logging to database as well as text file).